# FOREST ECOLOGY OF THE ALASKA TAIGA

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## ABSTRACT

The relationship of the Alaska taiga to subdivisions proposed for the boreal forests of Canada and Eurasia is discussed. The main vegetation types are classified and arranged on a temperature-moisture gradient.

Of special importance to taiga ecology is the complex relationship of vegetation and permafrost. Wildfire is also an important environmental factor in the Alaska taiga, and present-day vegetation mosaics reflect past fire history. Forest succession following fire is complex, whereas succession on newly deposited silt bars on river flood plains follows a simpler pattern.

In the past the Alaska taiga forests have been only lightly harvested for local use. Increased demands for wood fiber, accompanied by changes in ownership patterns resulting from the Alaska Native Claims Settlement Act, are increasing pressures on the taiga forests. An overall land plan is needed to insure continued production and preservation of the many resources of the taiga.

On discute de la relation existant entre la taïga de l'Alaska et les sous-divisions suggérées pour les forêts boréales du Canada et de l'Eurasie. Les principaux types de végétation sont classés et disposés en fonction d'un gradient température-humidité.

Les rapports complexes reliant la végétation et le pergélisol revêtent une importance toute spéciale pour l'écologie de la taïga. Les incendies hors contrôle représentent aussi, pour la taïga de l'Alaska, un facteur écologique important dont l'histoire est reflétée par les mosaïques de la végétation actuelle. La succession des stades forestiers faisant suite à un incendie est complexe tandis que celle des barres de silt récemment déposé dans les plaines inondables l'est moins.

Les forêts de la taïga de l'Alaska ont très peu été utilisées, par le passé, à des fins locales. L'augmentation de la demande pour les fibres ligneuses et les modifications apportées à l'Alaska Native Claims Settlement Act relativement aux droits de propriété ont pour résultat d'accroître encore plus les pressions s'exerçant sur la taïga. Une planificaton générale devra être effectuée si on veut maintenir la production et conserver les multiples ressources de la taïga.

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The taiga or northern coniferous forest is a vast band circling the northern hemisphere. It contains a relatively untapped resource of forest and wildlife. However, low energy inputs with associated low productivity, slow decomposition rates which tie up the nutrient pool, and permafrost underlying the northern sections of the taiga necessitate a large demand for basic ecological information as well as a cautious approach to human utilization of the forest and wildlife resources.

The purpose of this paper is to present a classification system for the common Alaska taiga vegetation types which can be used as an aid in resource management. The successional relationships of many of the vegetation types are discussed in order to provide information on the ecological processes of the taiga and the relationship of the vegetation types to the landscape. The delineation of at least two subzones in the taiga based on forest productivity, climatic parameters, or species distribution may provide for a better understanding of vegetation distribution.

There have been many discussions regarding the appropriateness of applying the term "taiga" to the Alaskan and other North American coniferous forests (see Hoffmann 1958). Although in some areas of central Alaska the deciduous component of the forest is dominant in successional stages, over most of Alaska the forests are primarily conifer, with a large percentage of bog or open forests characteristic also of the Siberian taiga. The term taiga as used in a broad sense to include the vast forests of the northern Soviet Union seems to be entirely appropriate for referring to the forests of Alaska if we exclude the southern and southeastern coastal areas.

## Zonation

There have been many attempts to classify the taiga or boreal forest into subzones, the subdivisions usually representing degrees of transition from the deciduous forests or grasslands and steppes in the south to the treeline and tundra in the north. Soviet biogeographers refer to three taiga subdivisions: the southern, middle, and northern taiga. Although these subdivisions are based to some extent on the general physiognomy of the vegetation, specific boundaries are usually related to tree species boundaries (Berg 1950). In addition, the Soviets recognize a forest tundra (lesotundra). Because of the lack of correspondence between the floras of North America and Asia,

the use of tree species for subzone boundaries makes it difficult to apply their zonation criteria to North American vegetation. However, from descriptions and from my own experience, I would say that the Alaska taiga falls primarily into the northern taiga and forest-tundra zones of Siberia.

Many of the existing zonation systems were reviewed in papers (Blüthgen 1970, Tikhomirov 1970, Hustich 1970, etc.) at the Helsinki symposium "Ecology of the Subarctic Regions" held in 1966, but no clear definitions of taiga, forest tundra, or subarctic resulted. More recently, Hare and Ritchie (1972) have reviewed the zonation of the northern taiga of both Eurasia and North America. They divided the northern forested regions into three zones: 1) the forest-tundra, a zone of isolated, often deformed and prostrate trees, set in a landscape of extensive tundra patches; 2) the open woodland, a zone dominated by open forests with a lichen-dominated forest floor and a discontinuous shrub layer; and 3) a closed forest. This classification seems to work well for the broad continental areas of both Canada and Siberia, but, as I will discuss later, does not entirely fit in the Alaska situation.

In discussing the zonation of the taiga, the scheme of Hamet-Ahti and Ahti should be mentioned (Hämet-Ahti 1965, Ahti et al 1968; and Hämet-Ahti and Ahti 1969). In the 1965 paper Hämet-Ahti compares this system with that of Hare for eastern Canada and that of two Russian authors for Canada and northern Russia. Hämet-Ahti's system is similar to that used by the Soviets in that it has hemiarctic, northern boreal, middle boreal and southern boreal zones (similar to forest tundra, northern taiga, middle taiga and southern taiga). However, the subdivisions do not equate directly with the Soviet taiga subzones, as Hamet-Ahti also describes a hemiboreal zone which corresponds to parts of the southern taiga zone of the Soviet Union.

None of these authors has applied his classification to the vegetation of Alaska. However, Hämet-Ahti (1975) did show a map at the 1975 Botanical Congress in Leningrad, in which most of the forested area of central Alaska was classified as "northern boreal." Hare and Ritchie (1972) recognize the special situation in Alaska in a section entitled "The Special Problem of Alaska." They point out that one reason for the difficulty in the delineation of zonal boundaries in the taiga of Alaska is the presence of high mountain barriers in precisely the areas where one would expect zonal boundaries to occur, i.e., the vicinity of the Brooks Range, at the northern tree limit, and the Alaska Range, which breaks up the general north south trends of climatic zones and creates a continental climate in the interior of Alaska. In addition, Hare and Ritchie point out that earlier attempts to link the treeline boundary of the taiga-tundra with the usual criteria, i.e., 10° July isotherm or the Nordenskjold line,[1] do not accurately depict the situation in western Alaska where a broad band of tundra covers the areas where the climatic indicators would imply that forests should be present. A third main factor complicating zonation in Alaska is the large river systems, which tend

[1] The Nordenskjold line is the isotherm of $T_w = 9 - 0.1T_k$, where $T_w$ and $T_k$ are mean daily temperatures (°C) for the warmest (w) and coldest (k) months.

to extend the forest environment to the west (Kobuk and Yukon Rivers) and the southwest (Kuskokwim River).

There have been two attempts to look at degree-day summations as a means of delineating the taiga of Alaska. Hopkins (1959) based his temperature summations on 10°C.[2] He found that it was possible to separate tundra from taiga on this basis in most cases, with the dividing line being roughly at 56°C degree-days and below for tundra and 56°C degree-days and above for taiga. Taiga stations at the edge of the forest in southwest Alaska tended to have up to 167°C degree-day summations, whereas those in northwest Alaska were close to 56°C degree-days. Along the south slope of the Brooks Range, the low-lying stations had degree-day summations of about 220°C, but all were located at elevations several hundred meters below treeline. To separate the taiga from the coastal Sitka spruce forests, Hopkins used an additional factor, temperature of the coldest month.

Funsch (1964),[2] using 6.1°C (43°F), also calculated degree-days for Alaska taiga stations but did not include any tundra stations in his analysis. His data show that the degree-day summations range from 944 in the warmest locations to approximately 555 at the outer fringes of the forested area.

If the temperature summation data from Funsch and from Hopkins are placed on the Alaska map, they show that any zonation of the Alaska taiga will not be from a south to north direction but rather in a semicircular pattern, with the most productive closed forests expected in the eastern and central interior along the Tanana and Yukon Rivers and with a predominance of open, more slow-growing forests to the north, west, and southwest. The same pattern has been shown for mean net radiation for Alaska by Hare and Ritchie (1972).

In support of this hypothesis, Farr (1967) found that the average site index for white spruce was greatest in the uplands near Fairbanks and along the Tanana River to the east and west of Fairbanks and much less to the north along the Porcupine River and the southeast in the Copper River basin. In general he found that the mean annual increment on the best site white spruce stands during the period of maximum development was from 1.7 to 3.6 cubic meters per hectare per year ($m^3$/ha/yr) in the Fairbanks area, from .86 to 2.5 in the Copper River area, and from approximately .75 to 1.5 in the Porcupine River area. These figures represent near-optimum wood production on forest sites within these regions.

Following the example of the Soviet biogeographers, another possible way to define zonation within the taiga is to base it on distribution of some individual tree and shrub species. The ranges of the Alaska trees and common shrubs have recently been mapped by Viereck and Little (1975).

The taiga zone in Alaska is usually delineated by the distribution of white spruce (Picea glauca (Moench) Voss). Black spruce (Picea mariana (Mill.) B.S.P.), on the other hand, shows a more limited distribution than white spruce in both the north and west but

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[2]One degree-day is accumulated for each °C above the daily mean of 10°C (or 6.1°C for Funsch). Thus, a daily mean of 15°C would accumulate 5°C (8.9°C for Funsch) for that day.

is found beyond the boundaries of white spruce only on the Kenai Peninsula, where the southern limit of white spruce is masked by contact and hybridization with Sitka spruce.

Tamarack (Larix laricina (Du Roi) K. Koch) has an even more limited range in Alaska than either spruce and is of special interest because it is rare in the warm Yukon Valley, where one might expect it to be common, but abundant in the Tanana Valley. It also shows a gap of several hundred kilometers with the nearest Canadian populations which have recently been mapped by Zoltai (1973).

Another tree, the distribution of which is of special interest, is the balsam poplar (Populus balsamifera L.). In discussions of treeline and forest limits, the presence of balsam poplar is often ignored. And yet, it is found far to the north and west of the limits of white spruce. On the arctic slope of the Brooks Range, it occurs not only as isolated well-developed stands at several warm spring locations, but it is also common on the fresh alluvium of most of the north-flowing rivers. In western Alaska it occurs as isolated clumps and individuals far out on Seward Peninsula. Although there is some speculation that the isolated occurrences north of the Brooks Range may be relicts from a somewhat warmer period, in most of the areas near treeline it seems to be vigorous and actively invading freshly deposited alluvium and other disturbed sites.

Aspen (Populus tremuloides Michx.), which is found on the warm and dry sites in the interior, is more limited in its regional distribution to those areas of the taiga with higher degree-day accumulations, although several outliers are found on dry warm sites to the west and southwest. However, its distribution might be useful in the eventual subzoning of the Alaska taiga.

There are a number of shrub species that show limited distribution within the taiga that might be useful eventually in delineating a warmer, more productive zone from a cooler, less productive area. Species which occur on warmer sites would include Ledum groenlandicum Oeder, Cornus stolonifera Michx., Arctostaphylos uva-ursi (L.) Spreng., Shepherdia canadensis (L.) Nutt., Elaeagnus commutata Bernh., Rubus idaeus L. var. strigosus (Michx.) Maxim., Salix lasiandra Benth., and S. interior Rowlee (see Viereck and Little 1975 for range maps). Ledum groenlandicum is an example from this group that is restricted to the warmer areas of the taiga and absent from the western areas with their cold summers. An extreme example might be Salix lasiandra, which is restricted in range primarily to the warmest taiga areas, with only occasional outliers to the south and west.

The forest map presented in "Alaska's Forest Resource" (Hutchison 1967) gives the best approximation of productive forest areas by separating the taiga into areas where there are well-stocked commercial stands (a term that is usually defined on the basis of forest productivity--commercial forest land being capable of producing more than 1.4 $m^3$/ha/yr and noncommercial land producing less than that amount). On this map, the commercial forested area corresponds most closely to the "predominately forest" subdivision of Rowe's (1959) forest map of Canada, and the noncommercially forested areas correspond most closely to Rowe's "forest and barren classification." For northwestern Alaska, this division is supported by Hettinger and Janz (1974), who state that the forest and open types of northwestern

Alaska on the south slopes of the Brooks Range fit into the "forest and barren" section of the Boreal Forest Region of Rowe.

There seems to be considerable evidence that it may be possible to subdivide the Alaskan taiga into at least two zones based on vegetation-type distribution and forest productivity, which in turn could be related to climate, especially temperature summations. However, until there is considerably more information on forest yield and until more of the vegetation is classified and mapped in detail, it would seem best not to set any definite subzonal boundaries.

Vegetation Types

There is surprisingly little vegetation information available for the taiga of Alaska and few quantitative vegetation analyses. As with much of our ecological knowledge, far more descriptive information exists for the tundra regions of the state than for the taiga. Hanson (1950, 1951a, 1951b, 1953) has described more plant communities in Alaska than any other author. In 1951 he stated, "Much research is needed on the composition, characteristics, and environmental relations of plant communities in many parts of Alaska in order that they may be classified, related to communities elsewhere in arctic, subarctic, and alpine regions, and used as an aid in land management." His statement on the need for more research in this field still holds true today. There have been no attempts at a vegetation classification system for the taiga other than the broad ones presented for the whole state, (Spetzman 1963, Joint Federal-State Land Use Planning Commission for Alaska (1973), and Viereck and Little (1972) or classifications for specific small regions such as that of Hettinger and Janz (1974) for the northeast corner of the state, or Hanson (1953) for northwestern Alaska.

However, with the increased interest and development in the Alaskan taiga, there is more demand for vegetation maps and for a more detailed classification system to use for mapping units. There is also a need for a taiga vegetation classification system that can be used as an indicator of site productivity for land management purposes.

I have reviewed 25 papers and reports that deal with the Alaska taiga vegetation. These publications are listed in Table 1. From this review, and my own experience with Alaskan vegetation, I have developed a classification of the Alaska taiga vegetation, using Fosberg's (1967) system that was designed for the International Biological Program (IBP). I have also followed, where appropriate, a classification used by Reid (1974) for an adjacent area in Canada. To make the classification strictly one of vegetation, I have purposely ignored topographic position and other environmental characteristics such as soil in the naming of these types. These vegetation types should eventually be characterized with respect to soil, topography, climatic parameters, and animal communities, thus making it possible to construct a true ecosystem classification. However, I believe that more information is needed before a realistic ecosystem classification can be made.

The main vegetation types of the Alaska taiga along with their IBP classification number are found in Table 1. No attempt has been made to include minor types or the many combinations of intergradations between the major types. It should be pointed out that the

vegetation of many areas of the Alaska taiga is relatively undescribed and that as additional information becomes available, refinements of the system will undoubtedly be possible.

In Figure 1, I have attempted to place each type along hypothetical temperature and moisture gradients. On the warmest and driest sites which occur on south-facing bluffs, there is a grass, steppe-like vegetation. On the more mesic sites there are the closed forest types and their successional stages, including aspen on south-facing slopes, birch and white spruce on the somewhat cooler and wetter sites, and closed black spruce stands on colder and moister sites.

The open forest stands separate into two groups: (1) those of the colder, drier sites near the altitudinal and latitudinal tree limit; and (2) open spruce stands on the colder and wetter sites, north-facing slopes, poorly drained lowlands and in the wetter, southwestern areas of the taiga.

Finally, on the coldest sites are the treeline shrub types and, on the wettest sites, bogs and fens.

Succession Following Fire

There is no one ecological theme that is more important to development and management of the taiga than that of succession. Most of the mosaic of vegetation in the taiga today results from young stands that have developed from disturbances, most of which are natural. These main disturbance factors are fire and river erosion and deposition. However, with economic development of the taiga, we find more and more examples of revegetation following manmade disturbances such as firelines, abandoned fields, gravel pits, mine tailings, and disturbances created by construction. Knowledge of the course of natural revegetation following disturbance is necessary for the management of the taiga forests. The information is also invaluable in planning for reforestation and artificial revegetation of man-disturbed sites.

Fire is undoubtedly one of the most important environmental factors affecting taiga ecosystems. Fire statistics for Alaska are impressive: between 1940 and 1969 the average annual burned-over area was approximately 400,000 hectares, 78 percent of this area having been burned by lightning caused fires. With the exception of a few isolated stands, the vast majority of the Alaska taiga has burned at least once in the last 200-250 years (Barney 1971). Stands older than 200 years are rare and found primarily on islands of the major rivers and in isolated locations near treeline.

Within the taiga and adjacent tundra areas, a breakdown of general types burned is as follows: conifer (primarily black spruce), 36 percent; mixed conifer-broad-leafed forests, 14 percent; broad-leafed forests (aspen, birch, cottonwood), 2 percent; treeless (tundra, bogs, and grassland), 43 percent; other, 5 percent.

These figures show that nearly half of what are generally termed "forest fires" actually occur in treeless areas, primarily bogs, fens, and tundra. Fire may be a more important factor in the structure of some of our tundra and bog types than has been previously acknowledged.

Within forested areas it is obvious that the conifer type (largely black spruce) is the most frequently burned and the greatest source of fire suppression problems. Their high susceptibility to fires is undoubtedly due to the abundance of ericaceous shrubs, the

low branches of the spruce, often dead and covered with highly flammable epiphytic lichens, and to the thick moss and lichen forest floor that becomes tinder dry after prolonged periods of little or no rainfall.

It is obvious also that fire susceptibility is low in the vast aspen and birch stands of the Alaska taiga. When fire reaches this type, it usually becomes a ground fire and moves more slowly than in the conifer type. The abundant successional stands of aspen and birch thus act as partial firebreaks, although fire will move through them following exceptionally dry periods. Thus, mapping the distribution of existing vegetation types should be extremely useful as an aid in formulating fire management and fire suppression plans.

There has been much published recently on the effects of fire on various vegetation types throughout the world and on revegetation following fire (Kozlowski and Ahlgren 1974, for example). This has been brought about primarily by a wide recognition of the positive effects of fire in some ecosystems and the necessity of fire to maintain natural vegetation in some areas. Fire effects in conifer and northern environments have been reviewed in two symposia: "Fire in the Northern Environment" (Slaughter et al. 1971), held in Fairbanks, Alaska, in 1970, and "The Ecological Role of Fire in Natural Conifer Forests of Western and Northern North America" (Wright and Heinselman 1973), held in Minnesota in 1972. Since that time there has been increased field work on the effects of fire on the taiga ecosystems in both Alaska and adjacent Canada (Rowe et al. 1974, for example).

Results of our studies of fire succession in the Alaska taiga indicate that in the black spruce, birch, and aspen types, the dominant tendency following wildfire is for the same forest type to come back almost immediately, with new, invading species being uncommon. There may be a brief intermediate shrub stage, but this too usually arises from the roots of willow and alder that were present in the stand before the fire. The successional sequence is due primarily to the reproductive mechanism of these species, all of which seem to be well adapted for fire.

Black spruce has semi-serotinous cones, and the seeds continue to fall from the cones for several years after fire. Paper birch is a profuse seed producer almost every year and also sprouts from the stem following fire; aspen, of course, produces tremendous quantities of root suckers following fire. White spruce, on the other hand, does not seed in directly after fire as commonly as the other species, due perhaps to its more infrequent seed-producing habits and to the fact that it does not store seed from year to year as black spruce does (Zasada 1971). As there are generally remnants of earlier successional stages, either aspen or birch, in all but the oldest of white spruce stands, the tendency is for either aspen or birch stands to follow white spruce. However, examples can be found where dense stands of white spruce, sometimes mixed with aspen or birch, form even-aged stands that seeded in directly after a fire.

Finally, with long periods of no fire the tendency is for the development of white spruce on dry, warm sites and black spruce and bog on the wetter sites. Whether the white spruce stands are actually stable or would eventually be converted to a black spruce site is still an unanswered question on upland sites because of the lack of old stands due to high fire frequency. Certainly around the fringes of

the taiga where white spruce occurs and black spruce does not, the successional sequence on some sites probably ends with a stable, open white spruce type.

Results of my study of succession after a 1971 fire in black spruce also indicate that most of the species coming in following the fire were already there before the fire. In fact, most of the shrubs and herbs have developed from below ground plants that were not burned by the fire. Subsequent spread by species such as Calamagrostis canadensis (Michx.) Beauv. and Epilobium angustifolium L. has been both by vegetative means and by seed. Although there was little change in the vascular flora, there was a rather drastic change in the moss and lichen layer. Marchantia polymorpha L. and Ceratodon purpureus (Hedw.) Brid. were not found in the unburned stand but became common in the burn, while the mosses and lichens of the mature stand were completely destroyed by the fire. Thus, the classical idea of a complete change of species with an invasion of pioneer species following severe disturbance by fire does not seem to hold true for the black spruce type in Alaska.

Succession on River Alluvium

A characteristic of most of the large rivers of the taiga is their broad flood plain with active erosion and deposition. The newly deposited alluvium provides an ideal example of classical textbook primary succession.

Figure 2 is a schematic diagram of some of my observations of forest succession on the Tanana River in interior Alaska. The normal successional pattern is in the center with willow and alder being replaced by balsam poplar and white spruce. The thickness of the line is meant to indicate the comparative frequency of the various routes.

Of special importance in this river succession is the relationship of the forest succession to soil development, especially the development of permafrost. On recently exposed silt or gravel bars soils are warm and well drained. Annual or more frequent flooding provides an ideal mineral soil seed bed for both willows and alders. Subsequent flooding may erode away or cover the younger seedlings with silt. However, Salix has a great ability to withstand heavy silting and will quickly send out adventitous roots. Once the alder and willow seedlings are several decimeters high, they are able to resist erosion and siltation and thus aid in the buildup of silt levels by slowing the flow of the river. Once the willow-alder/Equisetum type is well established, subsequent destruction is by undercutting from the sides of the stands.

Young shrub thickets on river bars are extremely productive. On the Tanana River, total biomass accumulation averaged 4.7 metric tons per hectare per year for a 20-year period (Van Cleve et al. 1971). At the same time, nitrogen fixation in root nodules of alder added considerable nitrogen to the soil--156 kilograms per hectare per year for a 20-year average. In a typical 20-year-old alder and willow stand, frequent flooding prevents the buildup of a thick litter layer. Therefore, soil temperatures remain relatively warm in comparison with later stages of succession.

Balsam poplar usually invades at the same time as the willows and alders. At first the poplar grows more slowly than the willows and alder and it is a rather inconspicuous element in the stands. However, from 20 to 40 years following the establishment of the

stands, the poplar overtops the shrubs and begins to shade them.

This balsam poplar/alder/Equisetum type constitutes the most rapid-growing forests of interior Alaska. Nutrients are readily available, soils are warm, and roots from the trees penetrate to the water table during much, if not all, of the growing season. Trees of 50-cm. diameter and heights of 30 meters are not uncommon in 80- to 100-year-old balsam poplar stands. In these stands a shrub layer of alder (Alnus tenuifolia Nutt.), Rosa acicularis Lindl., and Viburnum edule (Michx.) Raf. and a forest floor layer of Equisetum pratense Ehr. and Calamagrostis canadensis add significantly to the litter layer. However, occasional flooding prevents the development of a thick organic accumulation. Nevertheless, because of shading and some litter accumulation, soil temperatures are cooler than in the shrub stages.

Spruce invasion occurs in one of two ways in these river-bottom successional stands. Sometimes spruce seedlings germinate in large numbers on mineral soil at the time of flooding of willow stands. Usually subsequent flooding will destroy these seedlings before they reach sapling stage, but occasionally dense, even-aged spruce stands develop in this way. More commonly, there is a slower invasion of spruce during the balsam poplar stage, resulting in a well-developed understory of white spruce once the poplar stands reach 80 to 100 years of age.

With the slow change from poplar to spruce there is the beginning of the formation of a moss mat, primarily Hylocomium splendens (Hedw.) B.S.G. As the mosses develop, there is a rapid buildup of organic material. By this stage, flooding is infrequent and limited to the most severe flood years. In spite of cooler soil temperatures resulting from the insulating moss layers, tree growth is rapid, and most of the commercial stands of white spruce in interior Alaska are the white spruce/feathermoss type which have replaced balsam poplar.

Growth rings of older white spruce show that growth is greatly reduced after about 100 years. This slowdown of growth results from colder soil temperatures and, in some cases, the development of permafrost close to the surface. As colder and wetter soil conditions develop, the white spruce stands are replaced by slow-growing black spruce. Drury (1956) described this sequence from the Kuskokwim River and Viereck (1970a) from the Chena River; I have also seen many additional examples along the Tanana and Yukon Rivers and their tributaries.

Generally the conversion from balsam poplar to white spruce is essentially complete within 120 to 150 years. However, if a white spruce seed source is not available or if severe flooding reoccurs, balsam poplar stands persist for at least 200 years. Also, on islands protected from fire, and where flooding prevents accumulation of a thick organic layer, white spruce stands may be stable for at least 300 years.

On the older terraces the successional sequence is often complicated by wildfire. However, with or without fire, the main successional sequence is the development of the black spruce/feathermoss type closely underlain by permafrost. These may remain stable, but a mixture of black spruce stands and bogs develops on the older terraces. Disturbance of the surface under black spruce by natural causes such as fire, blown down trees, frost action, or water collecting in sphagnum mosses may result in the formation of thaw ponds

and bogs. As these are stabilized, the succession leads back to black spruce stands: thus, a cycle of black spruce and bog develops (Drury 1956). In other cases, black spruce stands may gradually change into bogs by the slow process of palludification: the development of a thick, water-logged sphagnum layer which eventually replaces the spruce. Succession after fire on the flood plain follows patterns similar to those of the uplands. Aspen and birch may replace both white and black spruce stands. However, river-bottom white spruce stands seldom burn, as they are usually protected by sloughs or oxbow lakes and they are not as flammable as black spruce stands. After fire black spruce stands are usually replaced directly by black spruce or by birch, but in areas underlain by coarse gravels, fire may result in the replacement of black spruce by aspen.

Land Use In the Alaska Taiga

In the earlier sections of this paper I described the vegetation of the taiga of Alaska and its possible division into subzones. In addition, using succession following fire, I have illustrated some of the more important processes affecting development of vegetation. I have left many gaps in my discussion, because data on vegetation and basic ecological processes of the Alaska taiga are inadequate at this time.

I would be remiss in my discussion of forest ecology if I did not mention the potential utilization of the forests in Alaska. Alaska is in the middle of the greatest upheaval in its history. Land ownership patterns established over the past 100 years are being drastically changed today. Land ownership is quickly passing from federal to state and private ownership, and control of large blocks of federal land will probably be shifted among the various federal agencies.

In 1958 under the Statehood Act, the state of Alaska was allowed to select 42 million hectares. Much of this land has already been selected and some has passed into private hands. Under the Alaska Native Claims Settlement Act of 1971, 16 million hectares will pass into Native ownership within the next few years; most has already been selected and some has been patented. At the same time, 32 million hectares or more will be permanently set aside for national parks, refuges, national forests, and wild rivers. Concurrent with this are the discovery of oil and the building of at least one trans-Alaska pipeline, increasing the population and demands for resources of all kinds.

All of these developments have brought on an acute need for resource information as a basis for land selection and land planning. Simultaneously, there has been a sharp increase in the demands on the Alaska forest resources which in the past have been small. Within the taiga zone, 32 percent is classified as forest land but only 21 percent of this, or 7 percent of the total area, is classified as commercial forest land. Although this is a small percentage of the land area, there are still vast timber reserves in interior Alaska, with an estimated total of 404 million cubic meters of commercially utilizable wood (Hutchison 1967). In the past, most use of these forests has been for local lumber and house logs. However, with the increased needs of the world for lumber and fiber, there has been an increased demand on the Alaska taiga forests. A chipping mill is in operation at Seward and trees from the taiga are being shipped to that port, for conversaion either to chips or cants, which are then exported.

The volume in 1975 is still small but expected to increase drastically in the future.

Being close to the climatic limits of our forest species, we must be cautious about the use of the northern taiga forests. Seed years are few in white spruce, and natural regeneration requires a mineral soil and a good seed source. Growth on many sites is marginally commercial and many stands have taken 150 to 200 years to develop. No data are available on the regeneration of hardwoods following cutting in interior Alaska because of their past low level of utilization. Being in an area near the climatic limits, disturbance such as large clearcuts may alter the environment in such a way as to prevent stand reestablishment. Overutilization of forests now may result in a future shortage of timber for local use.

The other 93 percent of the taiga, i.e., that not classified as commercial forest, should receive close attention. In these areas, wildlife production and utilization may be the most important potential use. New concepts in fire management in these types will undoubtedly be necessary to maintain the optimum wildlife conditions. In some areas, parks for instance, it will be necessary to preserve the natural ecosystem, which will necessitate a better understanding of the role of fire in the ecosystem.

More ecological information is needed before we can properly manage the interior forests for whatever their designated purposes. Information obtained from more temperate regions may be useful, but methods will have to be modified to take into account the northern environmental conditions. Considerably more research is needed in all aspects of ecosystem relationships if we are to avoid serious mistakes.

There is a need for the development of methods of revegetation with native species. This requires more basic knowledge of the autecology, especially reproduction ecology, of many of the common shrubs and herbs. Although much research has been undertaken in methods of revegetation with exotic grass species, little has been done with native plants. We must also guard against the possibility of the introduction of exotic species into the natural ecosystems in the taiga, where much of the land is frequently in a disturbed condition.

Willows are the most important colonizers of new surfaces in the taiga, yet little is known of their autecology, especially their reproductive biology and ecology. The Institute of Northern Forestry is actively involved in several studies of native shrubs because the information will be useful in revegetation and vegetative management. It has been found that it is possible to store some willow seed for up to 2 years and thus collect them before they are needed. We have found that some of the fall-seeding willows, such as Salix glauca, have a dormancy mechanism and require stratification for maximum germination (Zasada and Viereck 1975). We are also finding great differences in the ability of cuttings of various willow species to root when placed in the soil.

Finally, there is a need, especially now during the period of land claims settlement, for the establishment of a series of ecological reserves in the taiga from which we can gather baseline data for the monitoring of changes that will come with development. The need for such a system was pointed out at the subarctic ecology symposium in Finland in 1966. Although there has been progress in this

direction (the IBP sites in Canada, for instance), in Alaska there are still no areas within the taiga properly set aside and designated as research natural areas. One or more sites are needed in each of the major vegetation types in each of the major physiographic regions of Alaska. These reserves will ultimately be of great use in advancing our knowledge of the ecology of the Alaska taiga.

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| FORMATION CLASS (Fosberg 1967) | IBP UNIT (Fosberg 1967) | VEGETATION UNIT | REMARKS |
|---|---|---|---|
| Closed evergreen forests | 1A 17 (a) | (1) White spruce/feathermoss | Includes both upland and flood plain stands. The most productive forest sites. |
| | 1A 17 (a) | (2) Black spruce/feathermoss | On good, moderately drained sites, trees are tall and dense. Occasionally with Larix laricina. |
| | 1A 17 (a) | (3) Black spruce-white spruce/feather-moss | Transition or intermediate between 1 and 2. |
| Closed deciduous forests | 1A 21 | (4) Balsam poplar/alder/Equisetum | The common river flood plain type--variations by geographic area are apparent and need further description. Upland balsam poplar stands have not been described. |
| | 1A 21 | (5) Paper birch/alder/Calamagrostis | Abundant upland birch type--occasionally also on river terraces, usually following fire. |
| | 1A 21 | (6) Aspen/willow/Arctostaphylos uva-ursi | Common on south-facing slopes and occasional on well-drained river terraces following fire. |
| Closed mixed forests | 1A 17 (a)/1A 21 | (7) White spruce-paper birch/alder/ Calamagrostis | |
| | | (8) Black spruce-paper birch/Ledum | All represent stages of succession in which spruce is replacing the deciduous trees. |
| | | (9) Aspen-white spruce/Arctostaphylos uva-ursi | |
| | | (10) Aspen-black spruce/Ledum | |
| | | (11) Balsam poplar-white spruce/alder/ Equisetum | |

Table 1. A classification of Alaska taiga vegetation.[1]

| | | | |
|---|---|---|---|
| Open evergreen forests with closed lower layers | 1D 1 (a) | (12) Black spruce/Vaccinium/feathermoss | Moss is mostly Pleurozium schreberi, with some Hylocomium splendens. Usually permafrost but deep. |
| | | (13) Black spruce/feathermoss/Cladonia | With a low shrub layer of Ledum and Vaccinium uliginosum. Usually on drier sites; permafrost present, deep, or lacking. |
| | | (14) White spruce/dwarf birch/feathermoss | Outwash and river terraces and uplands near tree limits |
| | | (15) White spruce/dwarf birch/Sphagnum | Southwestern Alaska |
| Evergreen low savanna (scattered trees, woodland type) | 1J 14/1J 15 | (16) Black spruce/Sphagnum-Cladonia | Lichens and sphagnum "muskeg," occasionally with tamarack. Permafrost close to surface, poor drainage, successional stages, often with Eriophorum or Calamagrostis |
| | 1J 14 | (17) Black spruce/Cladonia | Dry site, black spruce near tree limits, "open lichen woodland." |
| | | (18) White spruce/dwarf birch/Cladonia | Treeline, Alaska Range, and south slopes of Brooks Range |
| | | (19) White spruce/Dryas/moss | Treeline, dry and exposed sites, south slopes of Brooks Range, north slopes of Alaska Range |
| Open deciduous forests | 1D 2 | (20) Paper birch-dwarf birch/Hylocomium | Near treeline in Brooks Range and northwestern Alaska |
| Open mixed forests | 1D 1/1D 2 | (21) White spruce-paper birch/Calamagrostis/Hylocomium | Treeline, Brooks Range |
| | | (22) White spruce-paper birch/alder/Sphagnum | Southwestern Alaska |
| Closed shrub | 1B 21 | (23) Willow-alder/Equisetum | Flood plain, successional stage |
| | | (24) Willow/Epilobium-Calamagrostis | Fire succession |
| | | (25) Dwarf birch-Ledum/Calamagrostis | Treeline |
| | | (26) Dwarf birch/feathermoss | Treeline and river terraces |
| | | (27) Alder/Calamagrostis | Treeline, especially southern and southwestern Alaska |

Table 1, cont.

| | | | |
|---|---|---|---|
| Closed grass | 1Q 2 | (28) Eriophorum tussocks | |
| | | (29) Sedge meadows | |
| | | (30) String bogs | |
| Seasonal short grass | 1M 2 | (31) Grass/Artemisia-Juniperus | Steep, south-facing bluffs; several grasses, Festuca altaica, Calamagrostis, Bromus, Elymus. A large number of additional grass types have been described by Hanson (1953). |
| Closed bryoid (moss) | 10 1 | (32) Sphagnum bog | |
| | 10 1 | (33) Low shrub/Sphagnum | Chamadaphne calyculata, Salix spp., and Betula nana are common. |

[1]Papers and reports reviewed for this classification are:

1. General maps and descriptions of Alaska vegetation: Spetzman (1963), U.S. Geological Survey (1970), Viereck and Little (1972), Joint Federal-State Land Use Planning Commission for Alaska (1973).
2. Central taiga region including upper Kuskokwim River: Baxter and Wadsworth (1939), Hanson (1951a), Drury (1956), Lutz (1956), Buckley and Libby (1957, 1959), Hanson et al. (1958), Johnson and Vogel (1966), La Roi (1967), Flemming (1968), Viereck (1970a), and Troth, Deneke, and Brown (1975).
3. Northeastern Alaska: Drew and Shanks (1965), Hettinger and Janz (1974).
4. Northwestern Alaska: Hanson (1953), Young (1974), Racine (1974).
5. Southwestern Alaska: Cahalane (1959), Williamson and Peyton (1962), Viereck (1970b).

Table 1, cont.

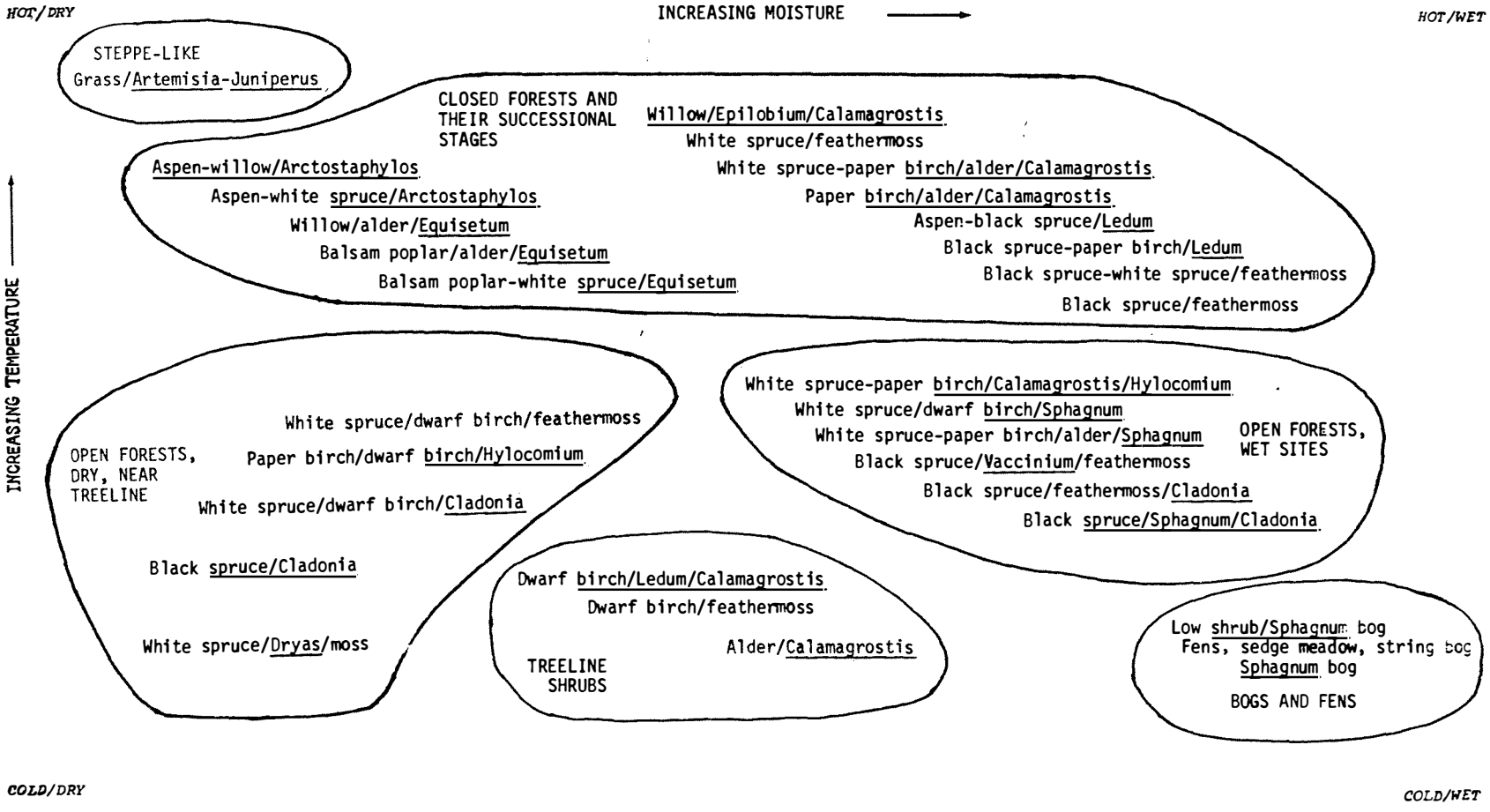


Figure 1. Alaska taiga vegetation types in relationship to moisture and temperature.

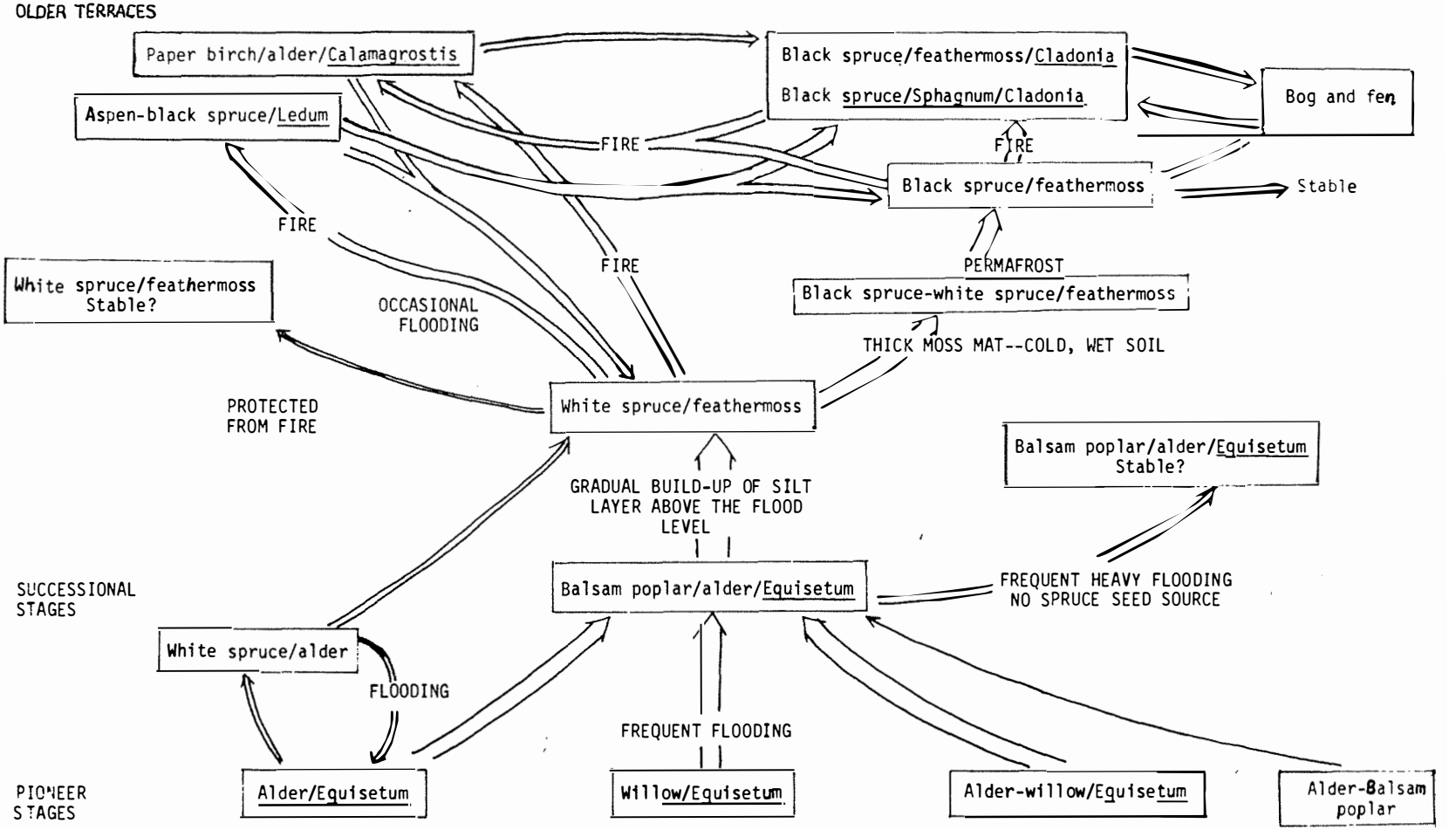


Figure 2. Successional patterns on the Tanana River, Alaska.

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